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A DEVICE FOR DETERMINING THE TOWING CAPACITY OF SMALL VESSELS

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DSTO

A Device for Determining the Towing Capacity of Small Vessels

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Abstract

The calibration of a variable drag device, known as the Variable Drag Sweep Simulator (VDSS), is described. It is used to measure the capability of wooden hull fishing trawlers to tow mine sweep gear.

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1. Introduction

The Royal Australian Navy intends converting a number of wooden hull fishing trawlers into small auxiliary minesweepers, MSA(S). Australian wooden hull fishing trawlers of interest to the RAN are only 15 to 25 m in length and it is necessary to measure the towing capacity of a fishing trawler prior to its acquisition for minesweeping. Deploying actual sweep gear would present a logistic and/or security problem so a lightweight device has been developed to simulate various types of sweep gear from a tow load, or hydrodynamic drag, viewpoint.

2. General Description of the Variable Drag Sweep Simulator (VDSS)

The VDSS is shown in Figure 1, and is constructed to RANRL Drawing No. 9/40/M5/1 (Issue 2). The angle θ is set to provide the same drag area A as the sweep gear of interest. By definition

$$A = \frac{\text{Tow load in N}}{1/2\,\rho V^2}\ \text{m}^2$$

ρ = density of water (kg m^{-3})

V = tow speed (ms^{-1})

θ is normally set between 0.262 radian (15°) and 0.524 radian (30°) in steps of 0.017 radian (1°).

The weights of components are:

Plates etc.	170 kg in air, 120 kg in seawater
INSHORE float	100 kg in air, -150 kg in sea water

3. Calibration

The VDSS has been calibrated by measuring tow load and tow speed for various values of plate angle θ.

3.1 Calibration in Jervis Bay

TRV TREVALLY towed the VDSS on 27 and 28 November 1984. TREVALLY ran down a laser beam transit at constant engine speed on reciprocal headings, 151° and 311° true. The TRV speed was about 4 ms^{-1} (8 kn) and it was tracked by a RANTAU theodolite tracking system over a period of 60 s. Tow speed was obtained as the mean of the ground speeds on the pair of reciprocal headings. Small differences in ground speed on different headings arose from wind, rather than current.

Tow load was measured using a Martin Decker 3000 kg f (30 kN) hydraulic dynamometer.

Five readings were taken at 15 s intervals over the 60 s period used to determine speed over the ground. The median tow load was calculated rather than the mean, since experience has shown that fluctuations in tow load are such that the median is a more accurate average than the mean when the number of readings is small.

The tow line was 100 m of braided polypropylene rope.

Results are shown in Table 1.

3.2 Calibration in Sydney Harbour

TRB BINCLEAVES towed the VDSS on 19, 20, 26 February 1985 and 1 March 1985 on reciprocal headings over the "measured mile" near Cockatoo Island. Runs were made at constant tow load, which was measured using the same dynamometer as TRV TREVALLY. Ground speed was calculated from the time required to run 1 nautical mile on reciprocal headings designated "EAST" and "WEST" in Table 2. The tow speed is the mean of the pair of speeds over the ground. The tow line was 50 m of braided polypropylene rope.

Table 1 Calibration of VDSS in Jervis Bay

Plate Angle, θ (rad)	Heading	Speed over the ground (ms^{-1})	Tow Load (kN)					
								Median
	151	3.90	5.99	6.28	5.94	5.91	5.98	5.98
0.262	331	4.09	6.18	6.18	5.89	5.98	5.89	5.98
	mean	4.00						5.98
	151	4.38	10.01	10.30	10.01	9.81	10.01	10.01
0.349	331	4.06	9.32	9.42	9.81	9.22	9.32	9.32
	mean	4.22						.66
	151	4.26	12.26	11.77	11.97	11.77	11.77	11.77
0.436	331	3.97	11.77	11.28	11.38	11.58	11.67	11.58
	mean	4.11						11.67
	151	4.13	14.22	13.54	13.34	13.44	13.44	13.44
0.524	331	3.89	12.95	13.34	12.75	13.64	13.24	13.24
	mean	4.01						13.34

Table 2 Calibration of VDSS in Sydney Harbour

Plate Angle, θ (rad)	Date	Tow Load (kN)	Speed over the Ground (ms^{-1})		Tow Speed (ms^{-1})
			West	East	
0.262	19 Feb	3.92	2.71	3.33	3.02
	20 Feb	4.41	3.40	2.81	3.10
	1 Mar	4.90	3.03	3.20	3.12
	1 Mar	5.40	3.33	3.46	3.40
	1 Mar	6.87	4.01	4.19	4.10
0.349	20 Feb	5.89	3.12	3.01	3.06
	26 Feb	7.85	3.75	3.52	3.64
0.436	20 Feb	7.36	2.94	3.29	3.12
0.524	19 Feb	7.85	2.81	3.05	2.93

3.3 Plate Angle Required for a Given Drag Area

Drag area A in Table 3 has been calculated from tow load and tow speed in Tables 1 and 2 using the expression

$$A = \frac{\text{Tow load in N}}{1/2\,\rho\,V^2}\ m^2$$

ρ = 1030 kg m^{-3} for sea water

V is tow speed in ms^{-1}

Table 3 Drag Area for VDSS

Plate Angle, θ (rad)	Tow Speed (ms^{-1})	Tow Load (kN)	A (m^2)	A/θ ($m^2\ rad^{-1}$)
0.262	3.02	3.92	0.834	3.18
	3.10	4.41	0.891	3.40
	3.12	4.90	0.977	3.73
	3.40	5.40	0.907	3.46
	4.00	5.98	0.726	2.77
	4.10	6.87	0.794	3.03
0.349	3.06	5.89	1.221	3.50
	3.64	7.85	1.150	3.30
	4.22	9.66	1.053	3.02
0.436	3.12	7.36	1.468	3.37
	4.11	11.67	1.341	3.08
0.524	2.93	7.85	1.776	3.39
	4.01	13.34	1.611	3.07

Mean values for data in Table 3 are listed in Table 4.

Table 4 Mean Values from Calibration Data

Plate Angle, θ (rad)	Tow Speed (ms^{-1})	A/θ ($m^2\ rad^{-1}$)
0.262	3.46	3.26
0.349	3.64	3.27
0.436	3.62	3.23
0.524	3.47	3.23

A/θ in Table 4 is for speeds of 3 to 4 ms^{-1} and is virtually independent of θ. The expression used to summarise the calibration is the least squares regression line in Figure 2.

$$A/\theta = 5.61 - 0.667\ V$$

The variation in A with speed at constant θ is due to planing of the INSHORE float at higher speeds. (The calibration relationship must break down at low plate angles since A/θ becomes infinite at zero plate angle).

The calibration graph shown in Figure 3 is based on the calibration expression

$$A = (5.61 - 0.667\ V)\theta$$

The vessel evaluation graph (Figure 4) used in practice for determining vessel towing capacity at 6 to 8 knots is based on

$$\text{Tow load} = \theta(5.61 - 0.667V)\ 1/2\ \rho V^2$$

3.4 Spot Check on Calibration

The calibration graph in Figure 3 was checked by TRV TREVALLY towing the VDSS in Jervis Bay on 1-2 June 1988. The RANTAU theodolite tracking system was unavailable, and runs were on a true heading of 295° near HMAS CRESWELL in perfectly calm conditions. The time was recorded for runs over a known distance (between beacon No. 2 bearing 205°T and the HMAS CRESWELL clock tower bearing 205°T). Tow load was recorded every 15 seconds on 1 June 1988 using a 30 kN Noble & Son strain gauge dynameter and on 2 June 1988 using a 3000 kg (30 kN) Martin Decker hydraulic dynamometer. An average of twenty two readings of tow load were taken on each run, and the mean values are listed in Table 5.

The calibration expression (Figure 3)

$$A/\theta = 5.61 - 0.667V$$

was used with the mean values of tow speed and angle in Table 5 to obtain predicted values of drag area. The predicted and measured values of drag area are listed in Table 6 and indicate that the calibration expression is accurate at large angles (0.524 and 0.541 rad).

Table 5 Check on Calibration

Date	Plate Angle, θ (rad)	Tow Load (kN)	Tow Speed (ms^{-1})	Drag Area, A (m^2)
1 Jan 88	0.524	11.83	3.69	1.688
		11.17	3.66	1.619
		11.17	3.69	1.593
		10.77	3.60	1.614
		10.34	3.41	1.727
		10.49	3.44	1.721
		mean	3.58	1.660
2 Jun 88	0.541	11.59	3.72	1.626
		11.57	3.64	1.696
		11.61	3.64	1.701
		11.69	3.68	1.676
		11.41	3.59	1.719
		11.37	3.54	1.762
		mean	3.64	1.697

Table 6 Comparison of Measured Drag Area with Predicted Value

		Drag Area	
Plate Angle, θ (rad)	Tow Speed (ms^{-1})	Measured (m^2)	Predicted (m^2)
0.524	3.58	1.66	1.69
0.541	3.64	1.70	1.72

4. VDSS Hydrodynamic Stability

The VDSS is stable in yaw. Even when θ is 0.564 radian (30 degrees) there is no evidence of stalling.

Being a homogeneous body the underwater body has no metacentric height, and stability in roll is only provided by the chain bridle. The effectiveness of the bridle increases as speed decreases, and at speeds above 4 ms^{-1} the roll stability is inadequate. The underwater body tends to become unstable in roll when the plate angle θ is less than 0.262 radian (15 degrees).

Stability in roll could be increased by adopting a shorter bridle, however this would bring the plates too near the surface for accurate calibration. If the tow line is too short the underwater body tends to plane to the surface since a short tow line exerts a nose pitching up moment. The minimum length depends on the height of the stern above the water, and is about 50 m for a TRB and 100 m for a TRV.

The VDSS is stable during turns.

5. Determination of Towing Capability of Small Vessels

The plate angle θ is set to provide the sweep gear tow load at the vessel's intended tow speed, using Figure 4. The vessel conducts two runs on reciprocal headings, and for each run records the engine (or propeller) speed required to attain the required tow load. The average of these two engine speeds is the speed required for towing the sweep gear. Any difference in engine speed arises from wind loading, not current, and the above mentioned averaging process will give a true value. If the vessel cannot attain the required tow load at maximum continuous engine speed it is unsuitable for towing the sweep gear.

5.1 Example of Towing Capability

As an example, a MSA(S) with a maximum continuous engine speed of 1500 r.p.m. is required to tow sweep gear which has a tow load of 9.81 kN (1 tonne) at 7.5 knots.

From Figure 4 the required plate angle is 24 degrees. During an evaluation using the VDSS with this angle the engine speeds required to achieve 9.81 kN on a dynamometer were 1350 r.p.m. on the first heading and 1400 r.p.m. on the reciprocal heading. Thus the MSA(S) can tow the sweep gear at 1375 r.p.m., which is 125 r.p.m. below maximum continuous speed.

6. Conclusion

A RAN TRB and a RAN TRV have been used to calibrate the Variable Drag Sweep Simulator by determining the relationship between drag area A (m^2) plate angle θ (rad) and tow speed V (ms^{-1}). At any given speed in the range of speeds of interest (3 to 4 ms^{-1}) the relationship is, to an acceptable accuracy,

$$A/\theta = 5.61 - 0.667V$$

This relationship is used to derive a vessel evaluation graph (Figure 4) to assist a small vessel in determining its suitability for towing sweep gear.

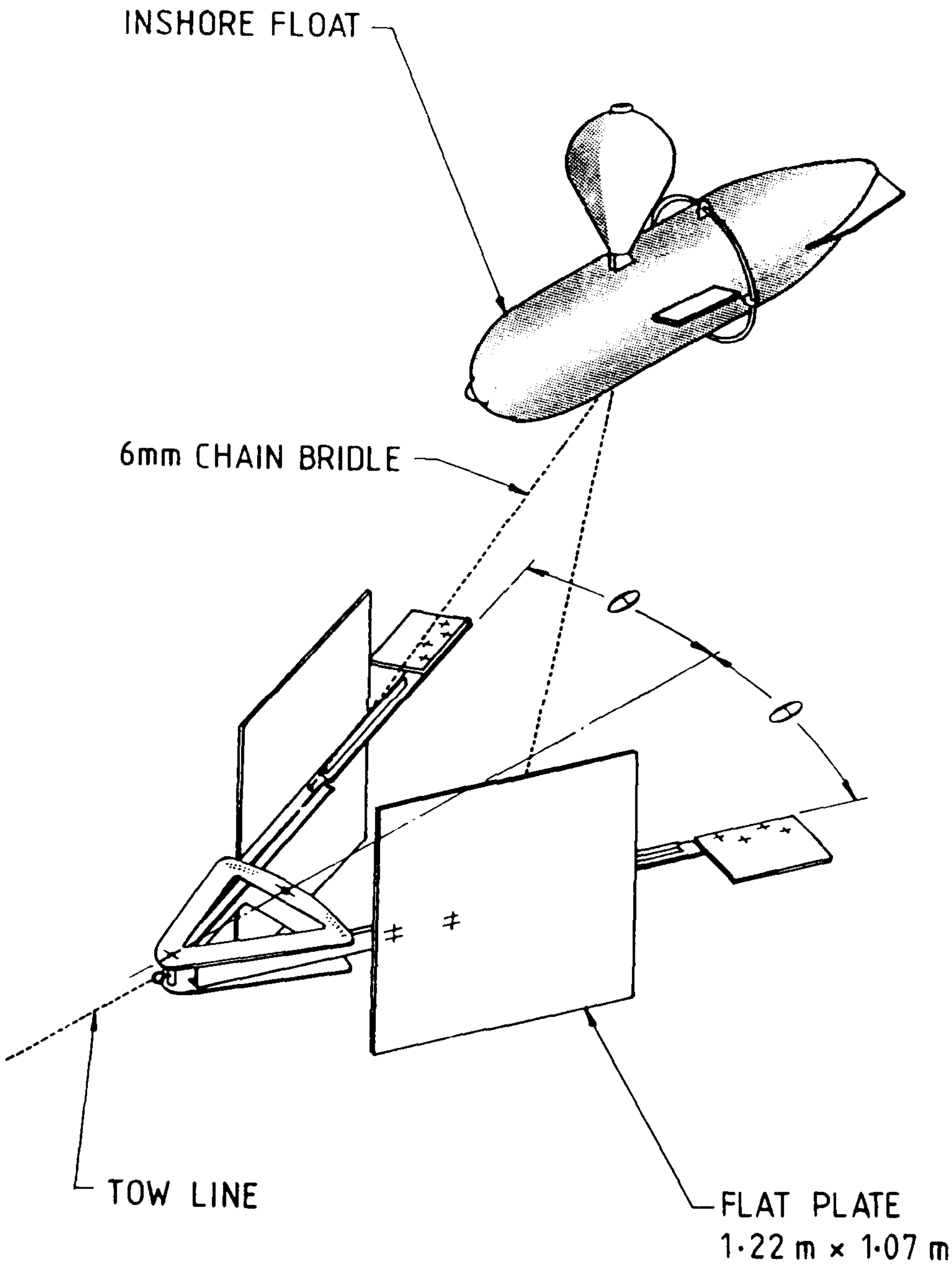

Figure 1 Variable Drag Sweep Simulator

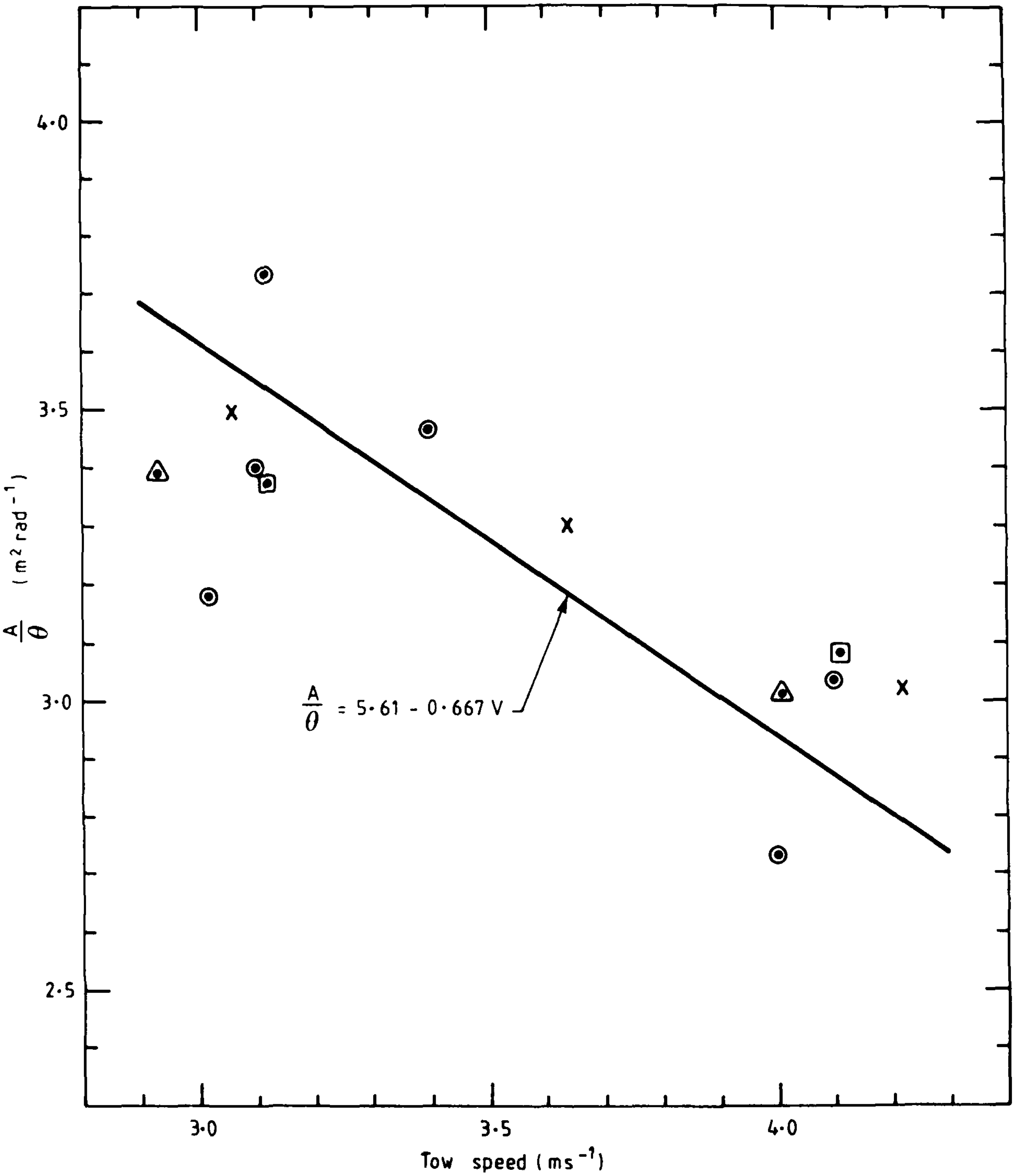

Figure 2 Variation in A/θ with tow speed

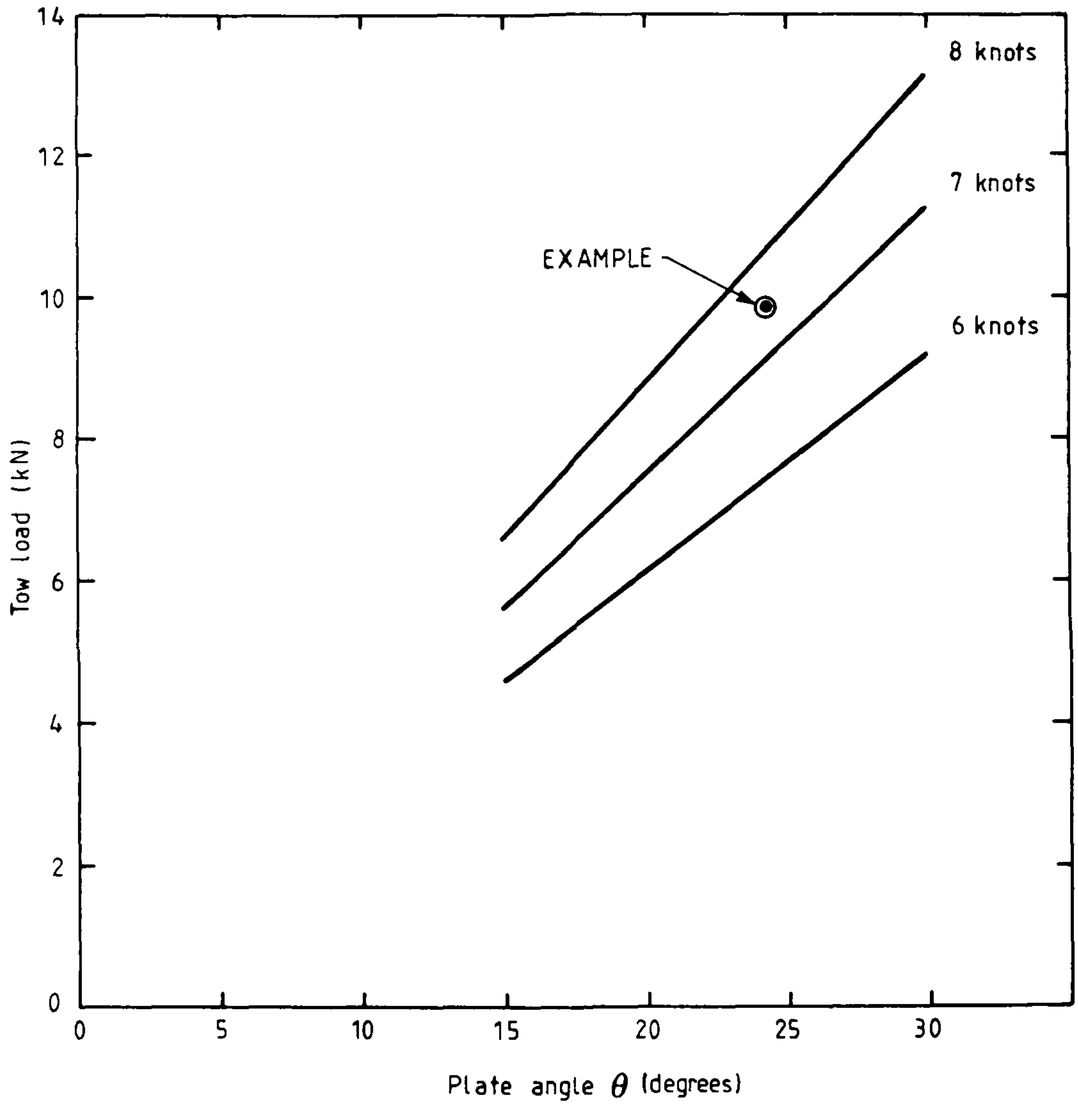

Figure 4 Vessel evaluation graph

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